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LAMINATED CERAMIC ELECTRONIC PARTSBACKGROUND OF THE INVENTION

Field of the Invention:

5 The present invention relates to laminated ceramic electronic parts and more specifically to laminated ceramic electronic parts such as a laminated ceramic capacitor and a laminated varistor having a structure in which a plurality of internal electrodes are disposed so as to overlap each other via ceramic layers within a ceramic element composing the electronic part.

Description of Related Art:

10 Ins B17 A surface mounted laminated ceramic capacitor which is one of typical laminated ceramic electronic parts is constructed by disposing external electrodes 24a and 24b which electrically conduct with a plurality of internal electrodes 22 at both ends of a ceramic element (capacitor element) 23 having a structure in which the internal electrodes 22 are disposed so as to face each other via ceramic layers 21a within dielectric ceramic 21 and
15 respective one ends of the internal electrodes 22 are led alternately to the opposite side as shown in FIG. 2 and is characterized in that it can obtain a large capacitance even though it is small.

20 By the way, with the miniaturization and the enhancement of capacity of the laminated electronic parts, the ceramic layer 21a within the laminated ceramic electronic parts such as the laminated ceramic capacitor have come to be thinned and a number of laminated layers thereof to be increased rapidly and those having a
25 structure in which a thickness of the ceramic layer 21a
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interposed between the internal electrodes 22 (effective thickness of element) is 5 μm and the number of lamination exceeds 100 have come to be put on the market.

The ceramic layer 21a has come to be thinned such that there is no big difference with the thickness of the internal electrode 22 in such laminated ceramic electronic parts and even one in which a rate of a total thickness of respective internal electrodes to a thickness of a ceramic element (chip) (thickness of internal electrodes (total)/thickness of ceramic layer) exceeds 0.30 has come to be provided.

Then, thereby, a sintering characteristic of the laminated ceramic electronic part, i.e. the product, is largely influenced by a sintering characteristic of a material of the internal electrode in a sintering process. As a result, there has been a problem that when the rate of the material of the internal electrode to the ceramic element increases, an incidence of delamination and crack increases in the sintering process, thus increasing a fraction defective and degrading the reliability. Further, such laminated ceramic electronic part has had a problem that it is liable to cause cracks when it receives a thermal shock.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to solve the above-mentioned problems by providing highly reliable laminated ceramic electronic parts in which delamination or ~~crack~~ ^{cracking} can be suppressed from occurring during ^{the} ~~a~~ sintering process and which excels in thermal shock resistance even if ^{the} ~~a~~ number of ~~lamination~~ ^{the} of internal electrodes is increased and ^{the} ~~a~~ thickness of ^{the individual} ~~a~~ ceramic layers is reduced. ^{located between the internal electrodes}

In order to achieve the above-mentioned object, the ~~present invention includes a~~ ^{present invention includes a} ~~laminated ceramic~~ ^{laminated ceramic} electronic part having a structure in which a plurality of internal electrodes are disposed so as to overlap each other via ^{respective} ~~ceramic~~ layers within a ~~ceramic element~~ and the internal electrodes are led to terminals on the opposite sides of the ceramic element ^{and in which each} ~~per layer is characterized in that it satisfies the~~ following requirements:

(a) ^{the} ~~a~~ thickness of ^{each respective} ~~the~~ ceramic layer is 10 μ m or less;

(b) ^{the} ~~a~~ number of ~~lamination of~~ the internal electrodes is 200 or more;

(c) ^{the} ~~a~~ ratio of the thickness of the internal electrode ^{to} the thickness of the ceramic layers (thickness of internal electrode/thickness of ceramic layer) ^{between} ~~is~~ 0.10 ^{and} 0.40; and

(d) ^{the} ~~a~~ ratio (volume of internal electrode/volume of ceramic element) of ^{the total} ~~a~~ volume of the internal electrodes ^{to} a volume of the ceramic element (total volume of internal electrodes and the ceramic) ^{is} 0.10 to 0.30. ^{ie., the combined material between and}

^{By satisfying the foregoing requirements, it} ~~it~~ becomes possible to suppress delamination and cracking

from occurring during the sintering process, to improve the thermal shock resistance and to provide ^a ~~the~~ highly reliable laminated ceramic electronic part even when the number of ~~lamination of~~ the internal electrodes is increased and the thickness of the ceramic layer is reduced. ^{By satisfying the} ~~By satisfying the~~

requirements of that the thickness of the ceramic layer is 10 μ m or less; the number of lamination of the internal electrodes is 200 or more; the ratio of the thickness of the internal electrode to the thickness of the ceramic layer (thickness of internal electrode/thickness of ceramic layer) is 0.10 to 0.40; and the ratio of the volume of the internal electrodes to the volume of the ceramic element

(volume of internal electrodes/volume of ceramic element) is 0.10 to 0.30.

That is, it becomes possible to ^{reduce} ~~suppress~~ the influence of the sintering characteristic of the material of the internal electrode during the sintering process and to prevent delamination and ^{cracking} ~~crack~~ from occurring during the sintering ^{process} by controlling the ratio of the thickness of the internal electrode to the thickness of the ceramic layer (thickness of internal electrode/thickness of ceramic layer). ^{It also} ~~and it~~ becomes possible to enhance the strength of the laminated ceramic electronic part against thermal stress and to provide the highly reliable laminated ceramic electronic part by controlling the ratio (volume of internal electrodes/volume of ceramic element) of the ^{total} volume of the internal electrodes to the ^{total} volume of the ceramic element ^{i.e., the} (total volume of internal electrodes and the ceramic) ^{material}.

The specific nature of the invention, as well as other objects, uses and advantages thereof, will clearly appear from the following description and the from the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING(S)

FIG. 1 is a section view showing a structure of a laminated ceramic electronic part (laminated ceramic capacitor) according to one embodiment of the present invention; and

FIG. 2 is a section view showing a structure of a prior art laminated ceramic electronic part (laminated ceramic capacitor).

DESCRIPTION OF PREFERRED EMBODIMENT

One preferred embodiment of the present invention will

be described below in detail. FIG. 1 is a section view showing a structure of a laminated ceramic electronic part (laminated ceramic capacitor in the present embodiment) according to the embodiment of the invention.

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As shown in FIG. 1, the laminated ceramic capacitor is constructed by disposing external electrodes 4a and 4b, which ^{are in electrical contact} ~~electrically conduct~~ with a plurality of internal electrodes 2, at ^{opposite} ~~both~~ ends of a ceramic element (capacitor element) 3, having a structure in which ^{e.g. a} ~~the~~ internal electrodes 2 are disposed so as to face each other via ceramic layers 1a within ceramic 1 and respective one ends of ^{each} ~~the~~ internal electrodes 2 ^{is coupled to external electrode 4a or 4b} ~~are led to the opposite side alternately.~~

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~~It is noted that in fabricating such a laminated ceramic capacitor, three kinds of green sheets whose thickness after sintering of either 9.8 μm , 6.2 μm or 4.3 μm , respectively, after sintering have been formed. Then, conductive paste for forming the internal electrode, was been printed on one surface of the green sheets such that they turn out to have thickness as shown in Table 1. Then, after laminating and compressing them such that a number of lamination of the internal electrodes turns out to be 200, they have been cut into a predetermined size (length L = 3.2 mm, width W = 1.6 mm) to obtain laminates (non-sintered ceramic element).~~

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~~After heat~~ ^{Ceramic element under predetermined} ~~Next, after treating the laminate by heat to degrease~~ ^{conditions} ~~and to sinter, under predetermined conditions, conductive paste for forming the external electrode has been applied on the both ends of the sintered ceramic element. Then, they have been sintered to form the external electrodes and the laminated ceramic capacitor as shown in FIG. 1 has been obtained.~~ ^{electrodes was} ~~the~~ ^{was produced} ~~Then,~~ ^{of the sample} characteristics of each laminated ceramic

capacitors were tested to determine the

¹ capacitor thus obtained, such as a value of electrostatic capacity, ¹ ~~to be obtained,~~ a value of insulation resistance, ¹ ~~the~~ an incidence of delamination, ¹ ~~and~~ an incidence of ^{cracking} crack on the surface of the ceramic element ¹ ~~as well as an incidence~~ of ^{cracking} crack (incidence of thermal shock crack) when a thermal shock ($T = 350^{\circ}\text{C}$) is applied ¹ ~~have been studied.~~ Table 1 shows the ¹ ~~result.~~ ¹ ~~results of these tests~~

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TABLE 1
layer

Thickness of Ceramic Layer

Thickness of Internal Electrode

Ratio of Thickness of Internal Electrode

Ratio of Volume of Internal Electrode

Value of Electrostatic Capacity

Value of Insulation
Resistance

	(μm)	(μm)	(-)	(-)	(μF)	log IR	(%)	(%)	(%)
* 1	9.8	0.68	0.06	0.075	1.81	12.01	0.00	0.00	0.00
2	9.8	0.99	0.10	0.100	2.25	12.00	0.00	0.00	0.00
3	9.8	1.13	0.15	0.112	2.37	11.98	0.00	0.00	0.00
4	9.8	1.97	0.20	0.186	2.43	11.87	0.00	0.00	0.00
* 5	9.8	2.50	0.26	0.307	2.23	11.98	0.33	1.35	2.13
* 6	6.2	0.58	0.09	0.095	2.78	11.53	0.00	0.00	0.00
7	6.2	0.87	0.14	0.135	3.54	11.25	0.00	0.00	0.00
8	6.2	1.15	0.19	0.172	3.42	11.15	0.00	0.00	0.00
9	6.2	1.87	0.31	0.257	3.15	11.01	0.00	0.01	0.00
*10	6.2	2.40	0.38	0.310	3.07	11.07	0.53	0.97	0.54
*11	4.3	0.41	0.95	0.103	3.98	10.10	0.00	0.00	0.00
12	4.3	0.71	0.16	0.170	4.54	10.93	0.00	0.00	0.00
13	4.3	0.97	0.23	0.200	4.95	11.25	0.00	0.00	0.00
14	4.3	1.23	0.29	0.210	5.01	10.98	0.00	0.00	0.00
*15	4.3	1.65	0.41	0.310	4.99	10.33	0.13	0.52	1.58
*16	4.3	2.40	0.56	0.390	4.83	10.54	0.97	1.35	3.51

Incidence of Delamination

Incidence of Cracking

Incidence of
Thermal Shock Cracking

It is noted that in Table 1, those samples marked with * ^{fall outside} ~~are those out of~~ the scope of the present invention (comparative examples) and the other samples ~~are those~~ within the scope of the invention.

Further, ^{The "Ratio"} ~~"Rate of Thickness of Internal Electrode"~~ is the ^{ratio} ~~rate~~ of the thickness of the internal electrode to ^{individual} ~~the~~ thickness of ^{each} ~~the~~ ceramic layer (thickness of internal electrode/thickness of ceramic layer) and ^{and the "Ratio"} ~~"Ratio of Volume of Internal Electrode"~~ is the ^{ratio} ~~rate~~ of the ^{total} ~~volume~~ of the internal electrodes to the ^{each} ~~volume~~ of the ceramic ^{element} ~~layer~~ (total volume of the internal electrodes and the ceramic).

Further, the ~~evaluating items~~ and a number of ~~evaluated~~ samples (n) in Table 1 ~~has had the following~~ relationship.

Electrostatic Capacity, Insulation Resistance ^{Resistance: $n \approx 100$}
n = 100

Incidence of Delamination and Cracking: ^{Cracking} $n \approx 500$
n = 500

Incidence of ^{Cracking} ~~Crack~~ due to Thermal Shock: $n \approx 500$
n = 500

As shown in Table 1, it has been confirmed that while
(1) the value of electrostatic capacity is small in Sample No. 1 whose ^{ratio} ~~rate~~ of the thickness of the internal electrode is below that of the scope of the invention (0.10 to 0.40),
(2) the value of insulation resistance is small in Sample No. 11 whose ^{ratio} ~~rate~~ of the thickness of the internal electrode exceeds that of the scope of the invention, and
(3) the incidences of delamination, ^{cracking} ~~crack~~ and ^{cracking} ~~crack~~ due to thermal shock are high in Sample Nos. 5, 10, 15 and 16 whose ^{ratio} ~~rate~~ of the volume of the internal electrode exceeds that of the scope of the invention (0.10 to 0.30), the samples within the scope of the invention which satisfy the

requirements of that the ^{ratio} ~~rate~~ of the thickness of the internal electrode to that of the ceramic layer (thickness of internal electrode / thickness of ceramic layer) ^{between} is 0.10 ^{and} to 0.40 and the ^{ratio} ~~rate~~ of the volume of the internal electrode to the volume of the ceramic element (volume of internal electrode / volume of ceramic element) ^{between} is 0.10 ^{and} to 0.30 can obtain characteristics which are practically no problem with respect to the values of electrostatic capacity and of insulation resistance, cause no delamination nor ^{cracking} ~~crack~~ during the sintering process and cause no ^{cracking} ~~crack~~ due to thermal shock.

It is noted that while the present embodiment has been explained by exemplifying ^a ~~the~~ laminated ceramic capacitor, the present invention is applicable not only to ~~the~~ laminated ceramic capacitors but also to various laminated ceramic electronic parts such as a laminated varistor having the structure in which a plurality of internal electrodes are disposed so as to overlap each other via ceramic layers within the ceramic element.

The present invention is not limited to the embodiment described above also in other points. That is, it is possible to add various applications and modifications thereto within the scope of the invention with respect to the thickness of the ceramic layer, the number of lamination of the internal electrodes, the rate of the thickness of the internal electrode to that of the ceramic layer, the rate of the volume of the internal electrode to that of the ceramic element and the like.

As described above, because the inventive laminated ceramic electronic part is constructed so as to satisfy the requirements of that the thickness of the ceramic layer is 10 μ m or less; the number of lamination of the internal electrodes is 200 or more; the ratio of the thickness of

the internal electrode to the thickness of the ceramic layer (thickness of internal electrode/thickness of ceramic layer) is 0.10 to 0.40; and the ratio of the volume of the internal electrode to the volume of the ceramic element is 0.10 to 0.30, it is possible to suppress the influence of the sintering characteristic of the material of the internal electrode during the sintering process, to prevent delamination and crack from occurring during the sintering and to enhance the strength of the laminated ceramic electronic part against thermal stress.

In accordance with the present invention is
As a result, it becomes possible to suppress
delamination and cracking from occurring during the sintering
process even when the number of lamination of the internal
electrodes is increased and the thickness of the ceramic
layer is reduced and to provide the highly reliable
laminated ceramic electronic part which excels in its
thermal shock resistance.

While the preferred embodiment has been described, variations thereto will occur to those skilled in the art within the scope of the present inventive concept which is delineated by the following claim.